An Introduction to Sendai Nuclear Power Station

Major Supply Facilities (As of the end of March 31, 2013)

Introduction

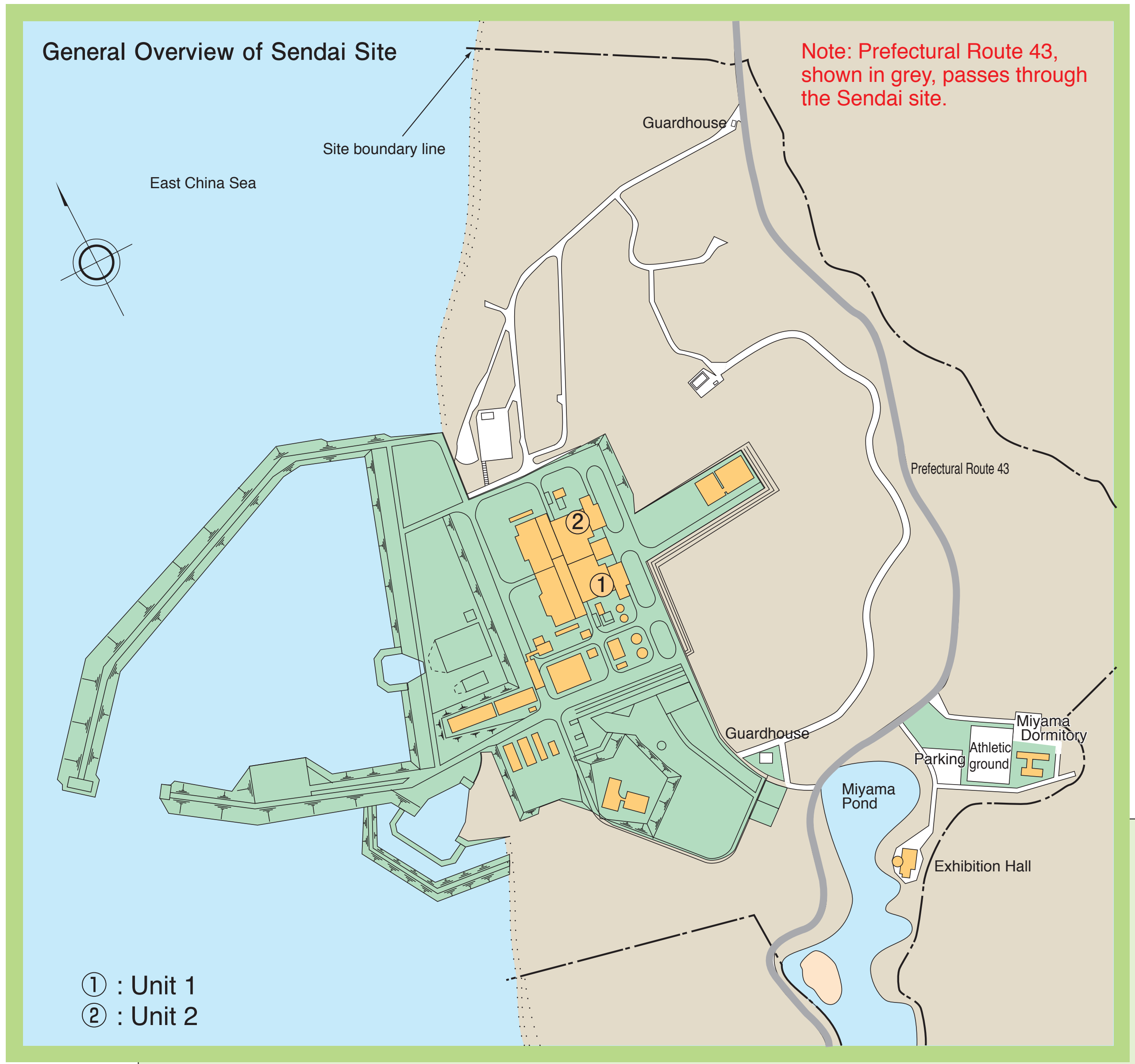
To ensure our customers of a stable supply of electric power today and in the future, Kyushu Electric Power is implementing a policy based on an optimal balance of energy sources, including primarily nuclear power but also high-efficiency thermal power plants and renewable energy sources. This policy was developed to address a wide range of issues including rising energy demand, energy security, the global environment and economy.

We operate two nuclear power generating units in Sendai, with the cooperation and support of the local community, and are now engaged in preparation for the construction of a third unit.

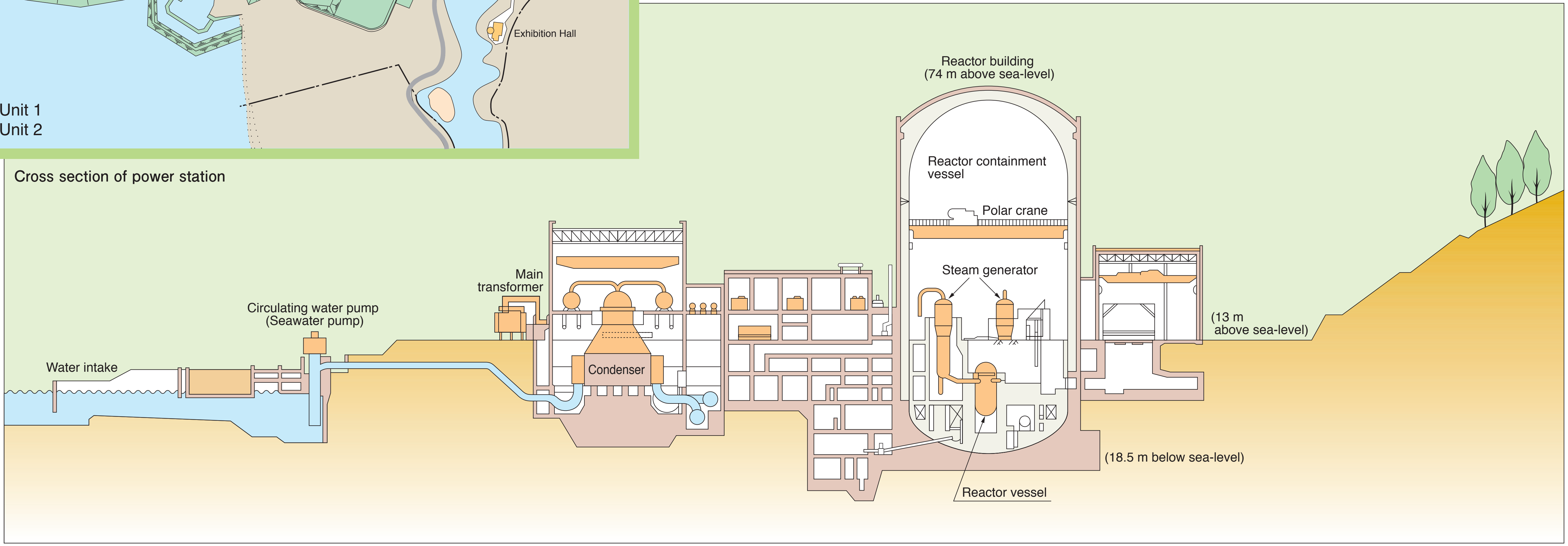
We will continue to earn the trust of local residents and other involved parties, keeping operational safety our top priority.

Aerial photograph of downtown Satsumasendai

A Guide to the Sendai Site



Item		Unit 1	Unit 2
Location		1765-3, Gumizaki-cho, Satsumasendai City, Kagoshima Pref.	
Site area		1.45 million m^2 (Includes approximately 100,000 m^2 of reclaimed land)	
Generated output		890MW	890MW
Reactor type		Light water moderated, light water cooled pressurized water reactor (PWR)	Light water moderated, light water cooled pressurized water reactor (PWR)
Fuel	Classification	Slightly enriched (Approx. 4 to 5%) uranium dioxide (UO_2)	Slightly enriched (Approx. 4 to 5%) uranium dioxide (UO_2)
	Loaded quantity	74 tons (Approx.)	74 tons (Approx.)
Commercial operation		July 4, 1984	November 28, 1985



Major Equipment and Systems

How nuclear power station work

The Sendai nuclear power station is a Pressurized Water Reactor (PWR).

The PWR design circulates the high-temperature, high-pressure water generated in the reactor core through the primary system, which is completely isolated from the secondary system used to supply steam from the steam generator to the turbine via the heat transfer tubes. Because they are independent systems, no steam containing any radioactive material is transported to the turbine side.

Inside the reactor core, uranium fuel is fissioned to release enormous amounts of heat. This heat is transferred to the steam generator by the water in the primary system, driven by the primary reactor coolant pump.

The primary system water pumped to the steam generator passes through the heat transfer tubes, transferring heat to the secondary system water on the outside of the tubes, and is then circulated back to the reactor.

The transferred heat causes the secondary system water to turn into steam, which is passed to the turbine, rotating the turbine and generator to generate electricity.

The steam is then passed to the condenser, where it is cooled by seawater, condensing into liquid to be circulated back to the steam generator again.

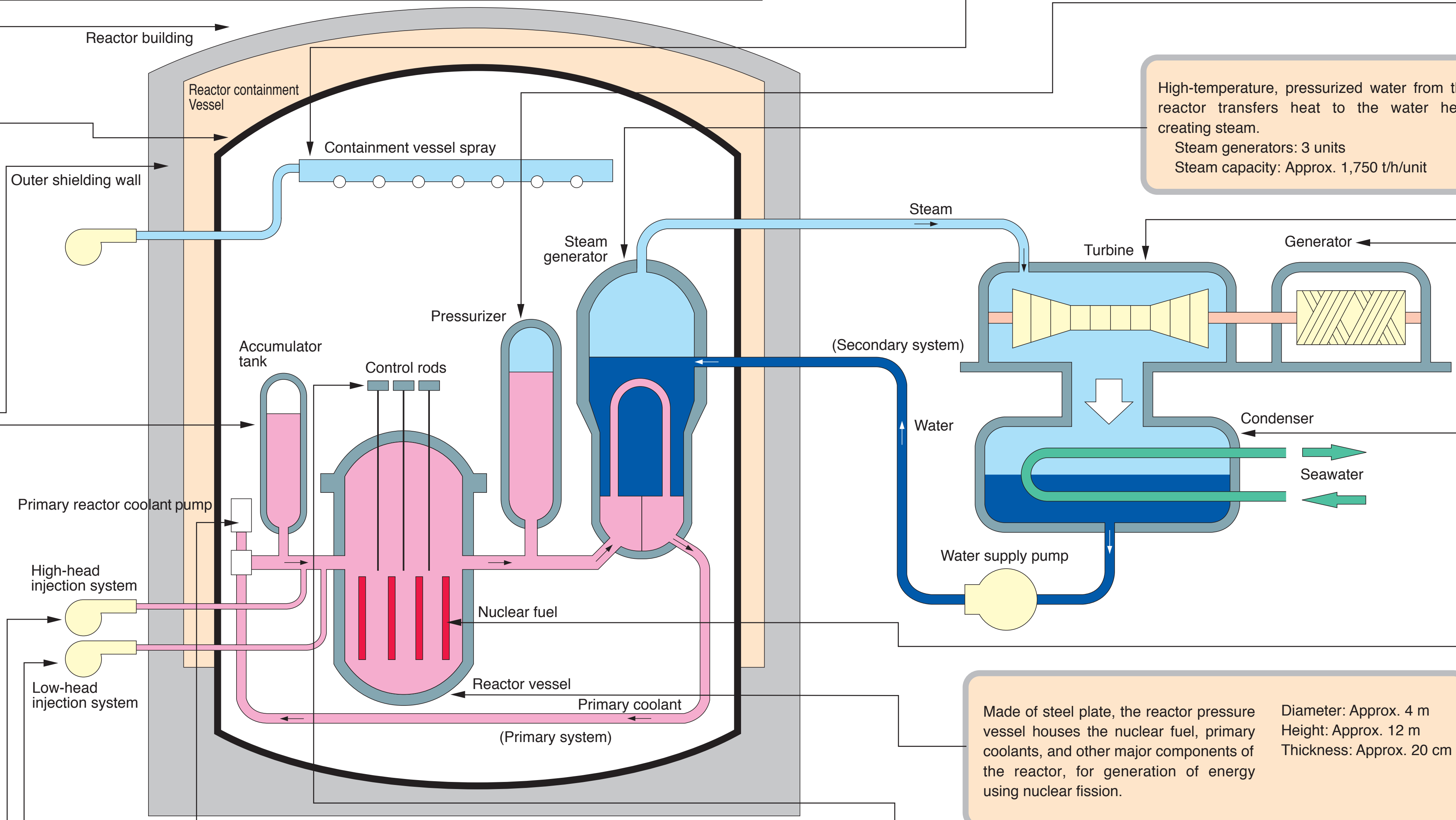
The Reactor Building consists of an outer shielding wall and a reactor containment vessel.

The reactor containment vessel is an airtight enclosure made of steel plate that completely encompasses the reactor, pumps, and other important equipment.

Diameter: Approx. 40 m
Height: Approx. 87 m
Thickness: Approx. 4 cm

The outer shielding wall is made of reinforced concrete.

Diameter: Approx. 44 m
Thickness: Approx. 90 cm



When the pressure inside the reactor containment vessel rises to abnormally high levels, water is sprayed inside to cool it off and limit the rise in pressure.

No. of systems: 2 Pumps: 2
Nozzles: Approx. 500 Capacity: Approx. 940 m³/h

Maintains the pressure inside the reactor at approx. 15.4 MPa (about 157 atmospheres). As a result, water inside the reactor will not boil even at approx. 320°C.

Qty: 1 unit

High-temperature, pressurized water from the reactor transfers heat to the water here, creating steam.

Steam generators: 3 units
Steam capacity: Approx. 1,750 t/h/unit

Steam from the steam generator turns the turbine.

Output: 890 MW (rated)
RPMs: 1800

Directly linked to the turbines rotations to generate electricity.

Capacity: 990 MVA
Voltage: 23 kV

Steam from the turbine is cooled with seawater, condensing it into liquid, which is pumped back to the steam generator.

Made of steel plate, the reactor pressure vessel houses the nuclear fuel, primary coolants, and other major components of the reactor, for generation of energy using nuclear fission.

Diameter: Approx. 4 m
Height: Approx. 12 m
Thickness: Approx. 20 cm

These absorb the neutrons causing nuclear fission, stopping the reactor.

The primary reactor coolant pumps circulate water through the reactor.

No. of units: 3
Capacity: Approx. 20,100 m³/h

Neutrons strike the uranium 235 in the fuel, triggering nuclear fission and releasing heat energy. The nuclear fuel (uranium) is sintered into pellets, and used inside sealed metal fuel rods.

Pellet diameter x length: Approx. 8 mm x 11 mm
Fuel rod length: Approx. 3.9 m
No. of pellets contained in one fuel rod: Approx. 320

The fuel rods are assembled into squares called fuel assemblies.

Qty. of fuel assemblies: 157
Qty. of fuel rods per assembly: 264

In the event of an accident, the emergency core cooling system floods the reactor pressure vessel with water. It consists of the following three systems.

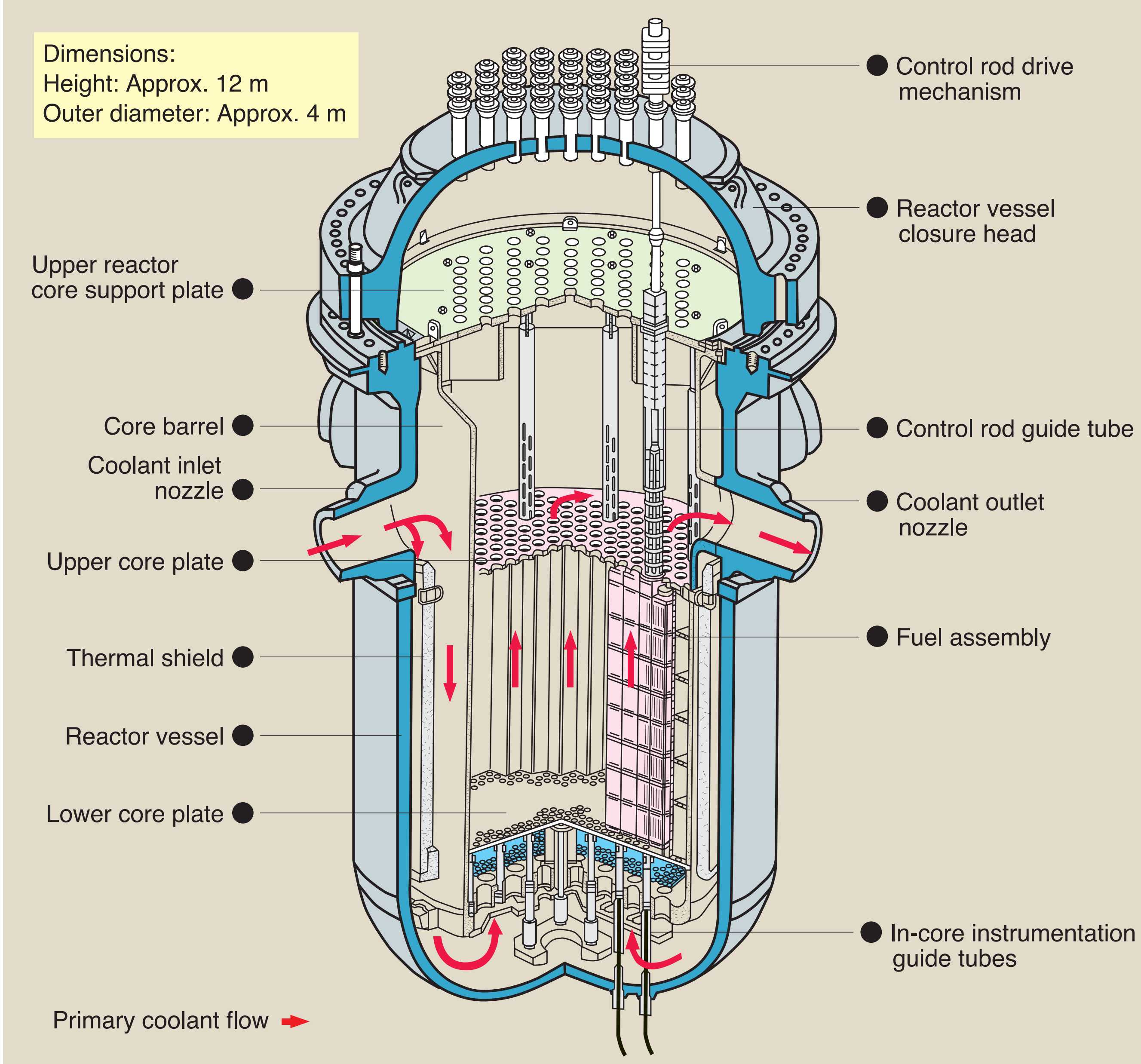
Accumulator injection system (tank)	High-head injection system (pump)	Low-head injection system (pump)
No. of units: 3	No. of units: 3	No. of units: 2
Capacity: Approx. 41 m³	Capacity: Approx. 147 m³/h	Capacity: Approx. 681 m³/h

Major Equipment Specifications

(same for both Units 1 and 2)

Equipment name	Item	Specifications
Reactor	Type	Light water moderated, light water cooled pressurized water
	Thermal output	2,660 MW
	Reactor outlet temperature	Approx. 321℃
	Reactor intake temperature	Approx. 284℃
	Primary pressure	Approx. 15.4 MPa (Approx.157 atmospheres)
Reactor Containment Vessel	Type	Upper part hemispherical, lower part torispherical cylindrical
	Dimensions	Inner diameter 40 m
		Total height Approx. 87 m
		(Above-ground height Approx. 61 m)
Steam Generator	Type	Heat exchange with vertically U-shaped piping
	Steam generation volume	Approx. 1750 t/h/unit (3 units installed)
Turbine	Type	Tandem compound 4-chamber, 6-branch exhaust reheat regenerative
	Output	890 MW (rated)
	Intake steam pressure	5.1 MPa (Approx. 52 atmospheres)
	Intake steam temperature	Approx. 266℃
	RPMs	1,800
Generator	Type	Laterally rotating magnetic field, 3-phase synchronous turbine generator
	Capacity	Approx. 990 MVA
	Voltage	23 kV
Main Transformer	Type	Outdoor-use unpressurized sealed
	Capacity	1000 MVA
	Rated voltage	Primary 23 kV
		Secondary 520 kV

Structure of the Pressurized Water Reactor

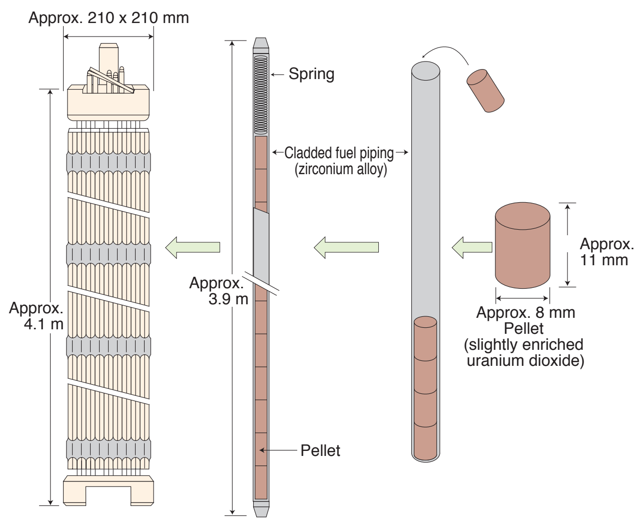


Nuclear Fuel

Nuclear fuel is uranium 235 enriched by about 4–5% to form uranium dioxide (UO2), which is sintered into hard pellets only the size of your fingertip, but large enough to hold plenty of fissionable material.

About 320 of these pellets are packed into a fuel rod, which is the name for cladded piping made of zirconium alloy

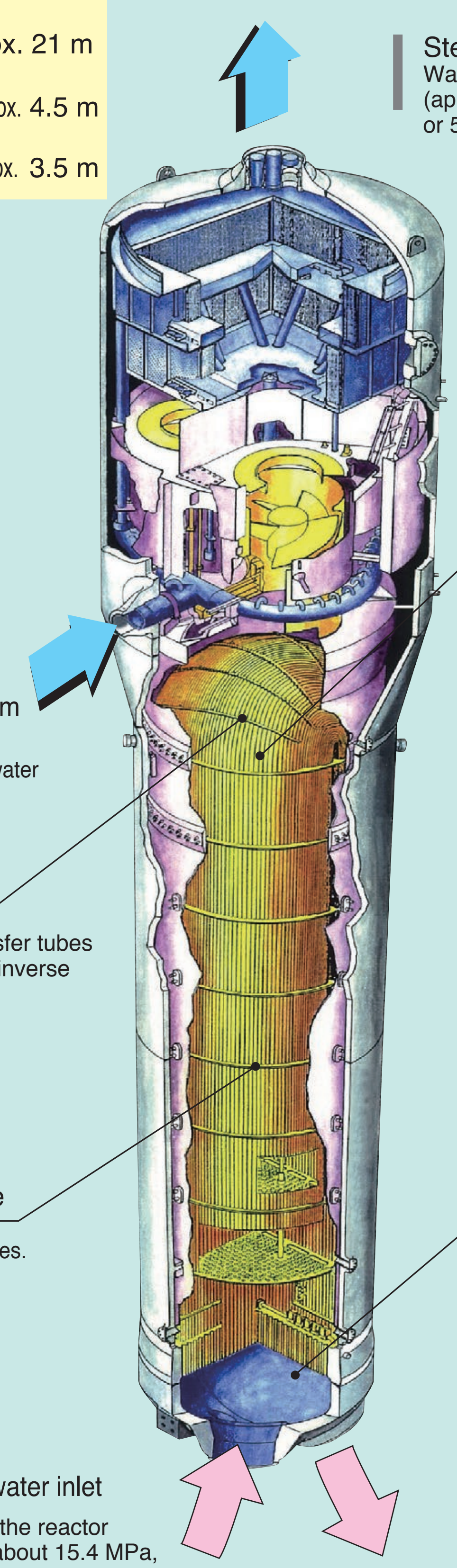
An arrangement of 264 of these fuel rods formed into a lattice grid makes up a fuel assembly, and 157 of these fuel assemblies are loaded at one time into the reactor.



Fuel assembly Fuel rod

Structure of the Steam Generator

Size
Height: Approx. 21 m
Outer diameter of upper part: Approx. 4.5 m
Outer diameter of lower part: Approx. 3.5 m



Steam outlet
Water is converted to steam (approx. 270°C at about 5.3 MPa, or 55 atmospheres), and sent to the turbine.

Tubes
- A large assemblage of tubes (approx. 3,400 tubes) is used to increase the available surface area, to facilitate the transfer of heat from the primary system water (flowing inside the tubes) to secondary system water (flowing outside the tubes).
- Tubes are made of Inconel alloy, which offers excellent corrosion resistance and strength.
- The inverted U-shape has an outer diameter of about 22 mm and a thickness of about 1.3 mm, and a total length of approx. 20–25 m.

Secondary system water inlet
Secondary system water enters here.

Anti-vibration bar
- Supports heat transfer tubes that are bent in an inverse U shape.

Tube plate
- Anchors the bases of the tubes.

Tube support plate
- Supports the fine tubes.

Primary system water inlet
Heated water from the reactor (approx. 320°C at about 15.4 MPa, or 157 atmosphere) enters here.

Primary system water outlet
After transferring heat, the water (approx. 280°C) returns to the reactor.

Earthquake Safety Measures of Nuclear Power Stations

1. Thorough preliminary investigation

Extensive site surveys are carried out on prospective sites to ensure that there are no active faults present, as they are prone to earthquakes. We also investigate the geology of the site, and the history of seismic activity in the region.

2. Nuclear power stations are built on the rock stratum

The rock stratum is a hard solid body that has formed over a very long time. Because the rock stratum inhibits amplification of earthquake-caused vibrations, the softer soil layers above the rock stratum are removed and the safety-critical facilities of the power station are built directly onto the rock stratum.

3. Earthquake-resistant designs reflect the level of safety severity

The facilities of a nuclear power station are classified according to the level of safety severity. Facilities with a high level of safety severity have been designed to withstand strong earthquakes.

4. Computers are used to confirm earthquake resistance

Computers are used to analyze the shaking of buildings (and the shaking of equipment caused by the shaking of the building) when they are subjected to seismic vibration that is set to levels considered by the earthquake resistant design. This process allows us to confirm the facilities have sufficient strength.

5. If a large earthquake is detected the nuclear reactor will be automatically scrammed

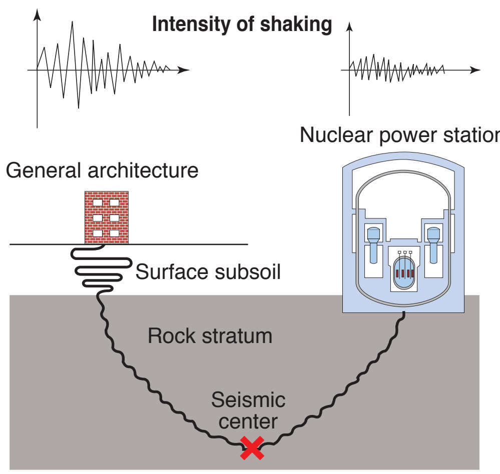
Seismic sensors are installed close to the rock stratum inside the power station buildings. These seismic sensors can output a signal that stops the nuclear reactor. If there is a large tremor in the rock stratum, the nuclear reactor scrams automatically to ensure safety is maintained.

"What is an active fault?"

When there is sudden slippage in the earth's crust, it is referred to as fault movement. This is what causes earthquakes. An active fault is an area of slippage in the earth's crust that has been experiencing repeated slippage some time in the period from the present to about 1,800,000 years ago, or where repeated slippage is expected to occur in the future.

"The difference in tremors in the firm rock stratum and the weaker surface subsoil"

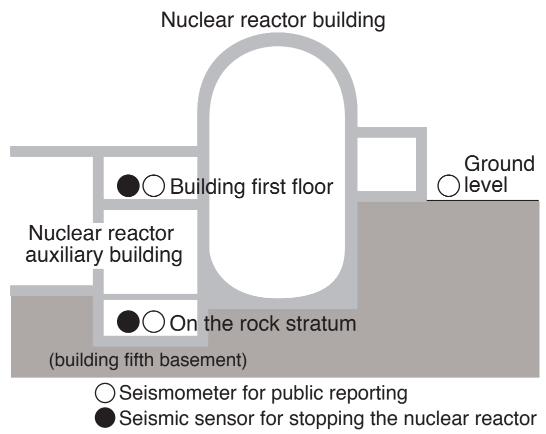
In contrast to the firm rock stratum, the weak structure of the subsoil amplifies earthquake tremors. Typically, tremors in the subsoil are 2 to 3 times greater than tremors in the rock stratum. This means that there is a big difference in the intensity of the shaking of a nuclear power station built directly on the rock stratum and the shaking of a building built on the weak-structured surface subsoil even when they are the same distance from the seismic center .



● Sendai Nuclear Power Station's Seismometer for Public Reporting

To facilitate the expedient public release of seismic data measured at the power station, three seismometers for public reporting are installed, one on the grounds of the power station, and two close to the location of seismic sensors that automatically stop the nuclear reactor in the event of an earthquake.

This seismic measurement data is sent online to Kagoshima prefecture and Satsumasendai city governments, and can be viewed at the Kagoshima Prefecture Environmental Radiation Monitoring Center and Satsumasendai City Hall.



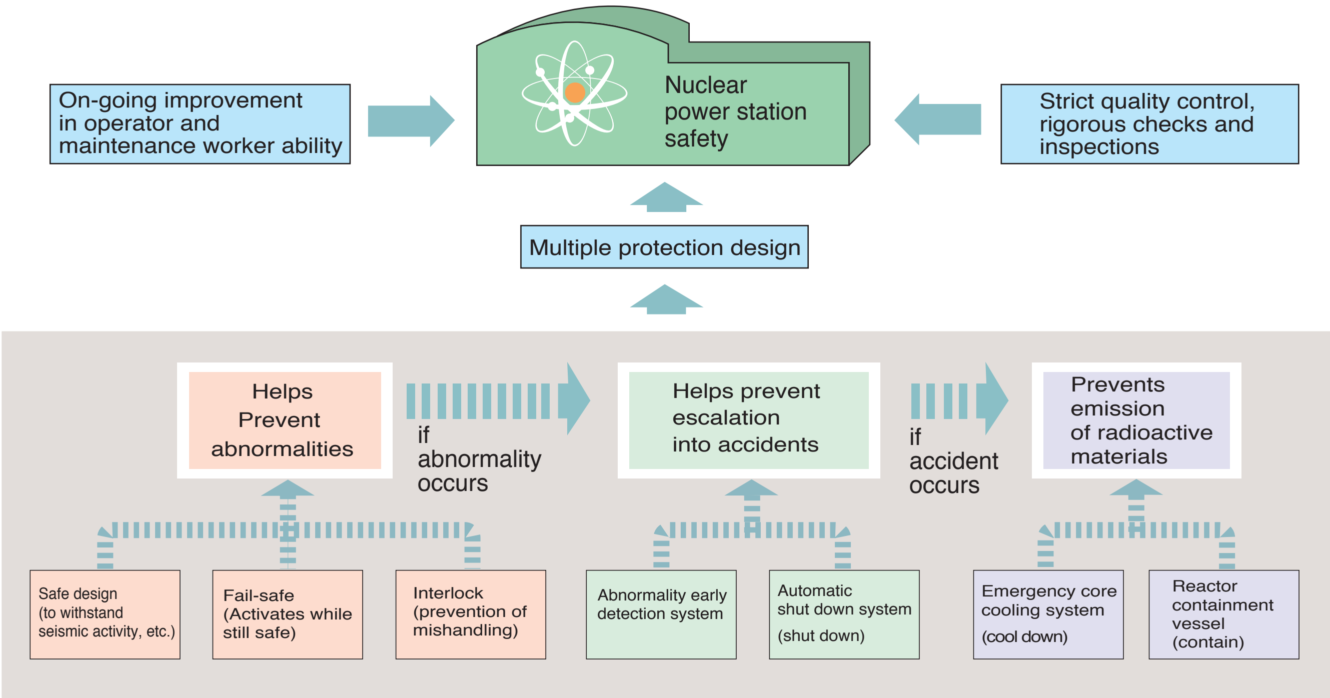
Safety in Nuclear Power Generation

Safety Features of Nuclear Power Station Design

The nuclear power station is designed to ensure safety, using multiple protection in a structure to completely seal away radioactive material from the outside world.

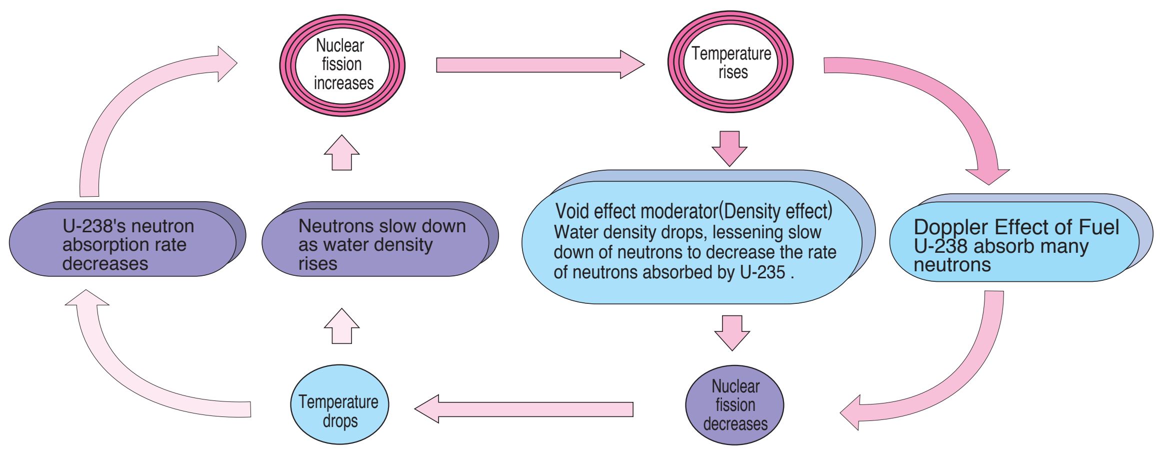
Under multiple protection, we implement a number of protection strategies in a multi-layered approach that recognizes that machines fail and people make mistakes. It includes the following safety measures:

- Designs and protocols to help prevent machines from failing, and people from making errors.
- Systems to immediately halt reactor operation in the event of an abnormality.
- Systems to cool the reactor and contain radioactive material in the event of an accident.



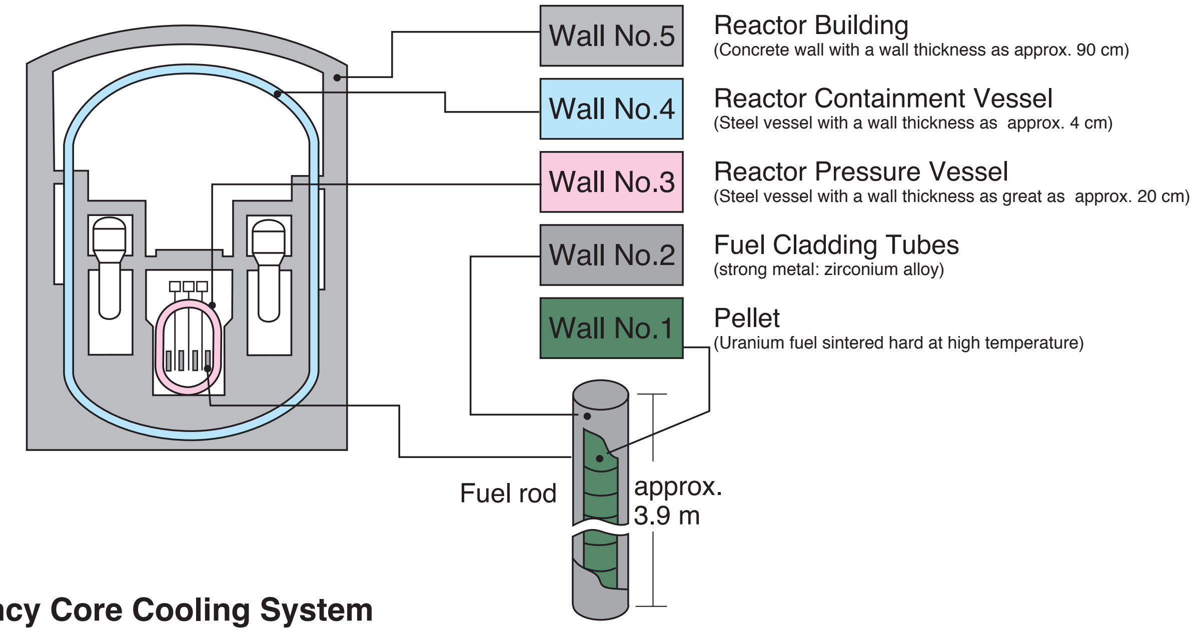
Self-regulation

When the temperature of the reactor core rises sharply for any reason, the nuclear fission chain reaction automatically slackens, causing the temperature to drop again in a self-regulating design that offers excellent operational safety.



Five Walls of Protection

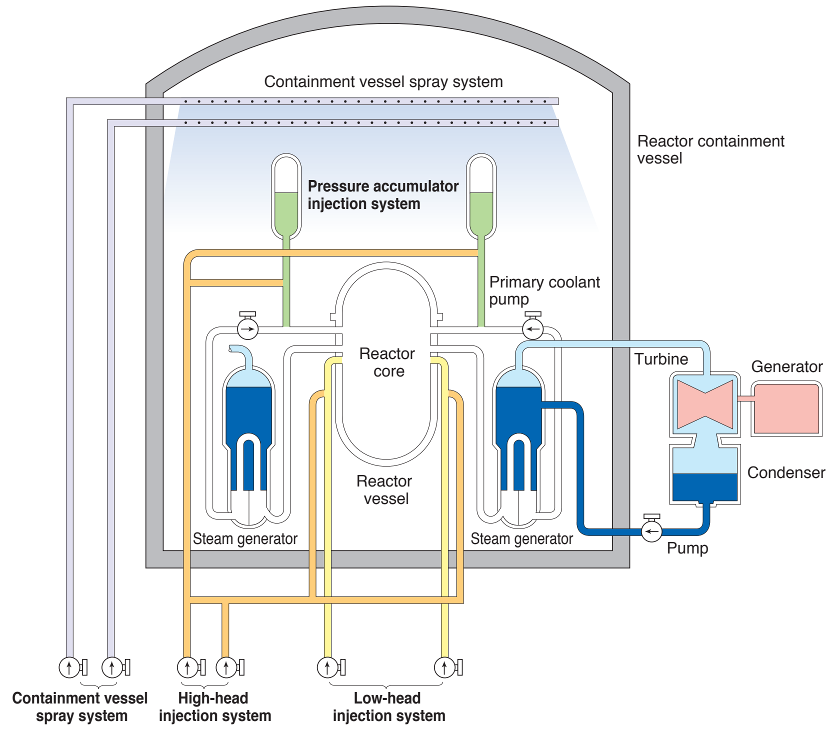
The radioactive material generated by fission of the uranium 235 fuel is secure behind multiple barriers, preventing it from escaping into the surrounding environment.



Emergency Core Cooling System (ECCS)

At a nuclear power station, the worst-case accident scenario is for the primary system piping or similar equipment to rupture, causing a loss of water from the system and leaving the reactor core in a dangerously bare state.

Even in this kind of unlikely accident, however, the Emergency Core Cooling System (ECCS), which consists of an accumulator injection system, a high-head injection system, and a low-head injection system, injects water into the reactor to cool it down, thus ensuring operations safety.



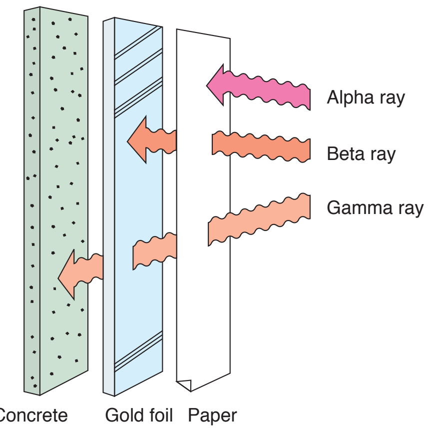
Radioactivity and Radiation

Types and Radiation, and Their Properties

The ability to generate radiation is called radioactivity, while substances that possess this radioactivity are called radioactive substances. Taking the electric light as a familiar example, where the light bulb would be the radioactive substance, the light rays emanating from the light bulb is the radiation, and the ability to generate the light is radioactivity.

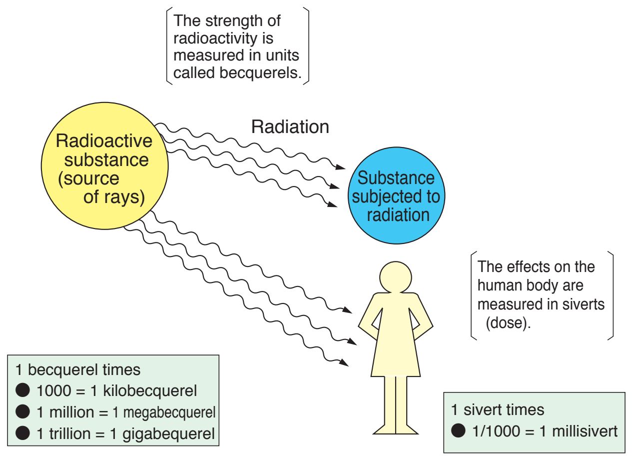
Radiation can include alpha rays, beta rays and gamma rays.

- Alpha rays are identical to the nucleus of the helium atom. With little ability to pass through solid objects, they can be stopped by a single sheet of ordinary paper.
- Beta rays are electrons, and are much more capable than alpha rays of passing through solid objects. Nevertheless, thin gold foil is enough to stop them.
- Gamma rays are like X-rays, in that both are electromagnetic waves, and pass through solid objects with great ease. Only a thick sheet of lead, or a concrete wall, is barely capable of stopping them.



Radioactivity Weakens Over Time

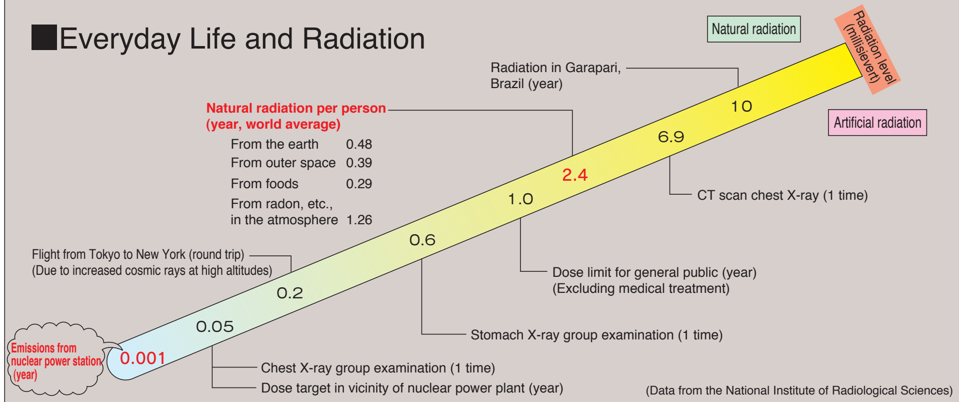
The nucleus of a radioactive substance decays whenever it emits radiation, mutating successively into other substances until it reaches one that is not radioactive. The time required for a substance to give off radiation and change from that substance into a different substance is measured in terms of lives, and is strictly determined for each type of radioactive substance. The time required for the original radioactive level to weaken by one-half is called a half-life, and is the method used for measuring the life of radioactive substances.



■Units of radioactivity and radiation

		Unit	Definition
Unit of radioactivity		Becquerel (Bq)	Amount of radioactive substance where one nucleus decays over a period of one second
Units related to amounts of radiation	Absorbed dose	Gray (Gy)	This unit of measurement expresses how much radiation energy has been absorbed by a material (any material, including people). 1 Gy represents the dose when 1 joule of radiation energy is absorbed for every 1kg of material.
	Dose	Sivert (Sv)	Biological effects ratio of grays

■Everyday Life and Radiation



(Data from the National Institute of Radiological Sciences)

■Natural Radiation Levels in Kyushu Prefectures

Fukuoka Pref.	1.10
Saga Pref.	1.06
Nagasaki Pref.	1.00
Oita Pref.	1.01
Kumamoto Pref.	0.98
Miyazaki Pref.	1.03
Kagoshima Pref.	0.98

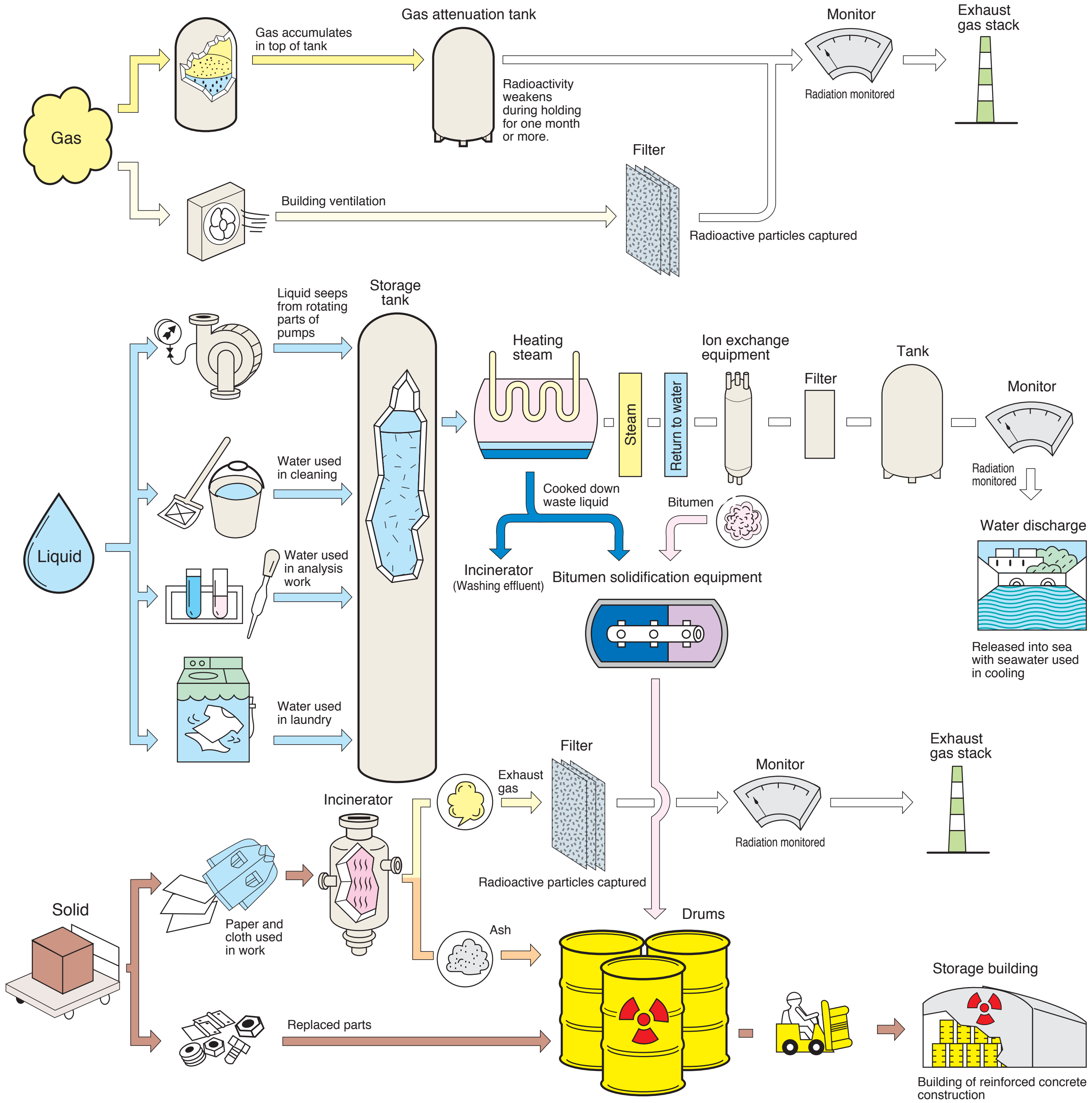
- Natural radiation levels are the sum of cosmic rays, radiation from the earth, and amounts ingested from food. In millisiverts/year
- Excluding radiation from radon and other similar sources.

Treatment of Radioactive Waste

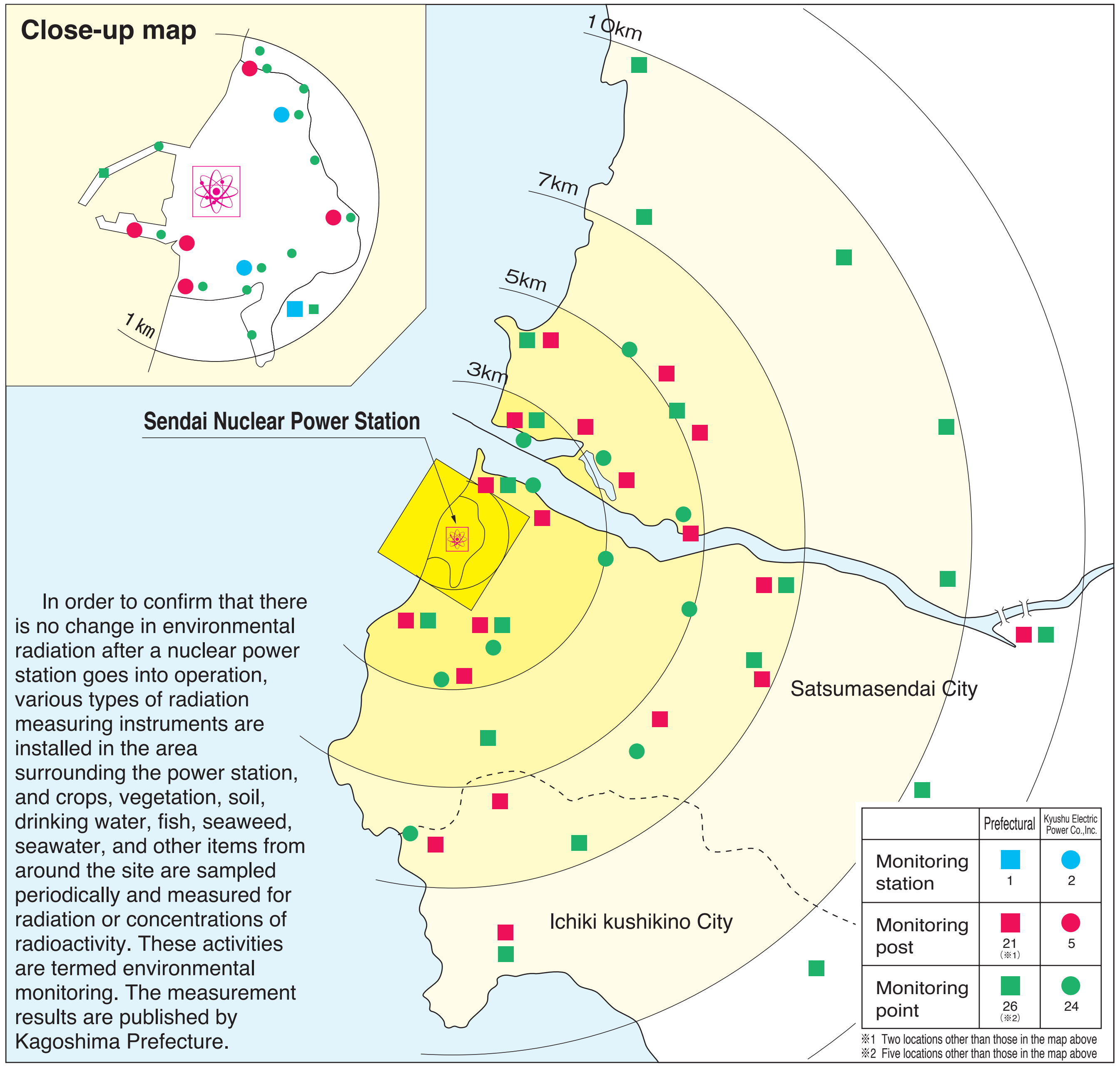
The nuclear power station generates gaseous, liquid and solid radioactive waste in operation. This is called low-level radioactive waste, because of the low intensity of the radiation it emits.

Gaseous and liquid waste is treated by on-site waste processing equipment. Radioactivity is measured and safety verified before the treated waste is then released to the sea or atmosphere. To minimize effect on the surrounding environment, radiation levels cannot exceed natural background radiation. Solid radioactive waste is incinerated, compressed and treated before being packed into drums for temporary storage on-site.

Treatment of Radioactive Wastes Generated by the Nuclear Power Station



Environmental Monitoring



In order to confirm that there is no change in environmental radiation after a nuclear power station goes into operation, various types of radiation measuring instruments are installed in the area surrounding the power station, and crops, vegetation, soil, drinking water, fish, seaweed, seawater, and other items from around the site are sampled periodically and measured for radiation or concentrations of radioactivity. These activities are termed environmental monitoring. The measurement results are published by Kagoshima Prefecture.

	Prefectural	Kyushu Electric Power Co.,Inc.
Monitoring station	1	2
Monitoring post	21 (※1)	5
Monitoring point	26 (※2)	24

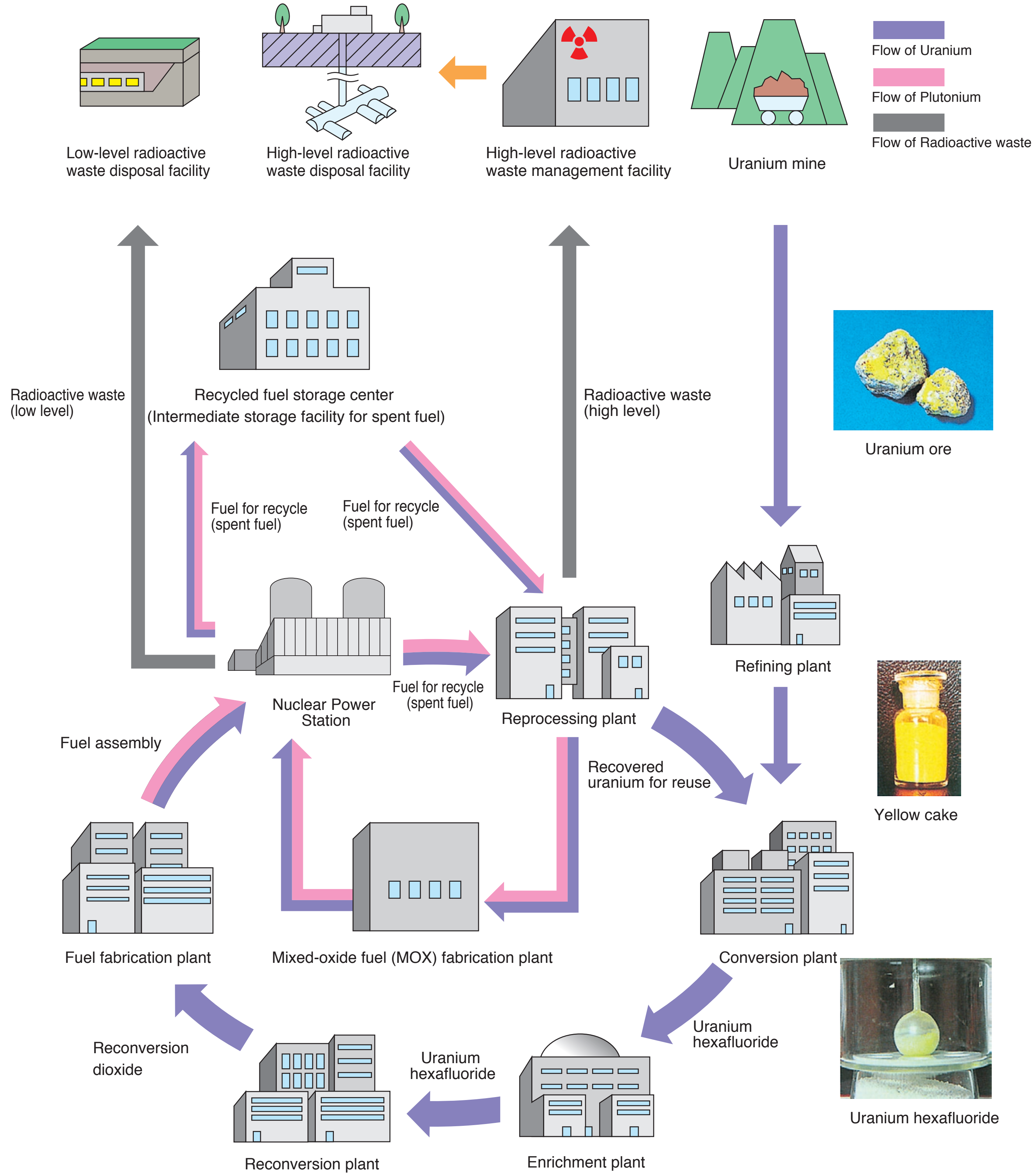
※1 Two locations other than those in the map above
※2 Five locations other than those in the map above

Monitoring station

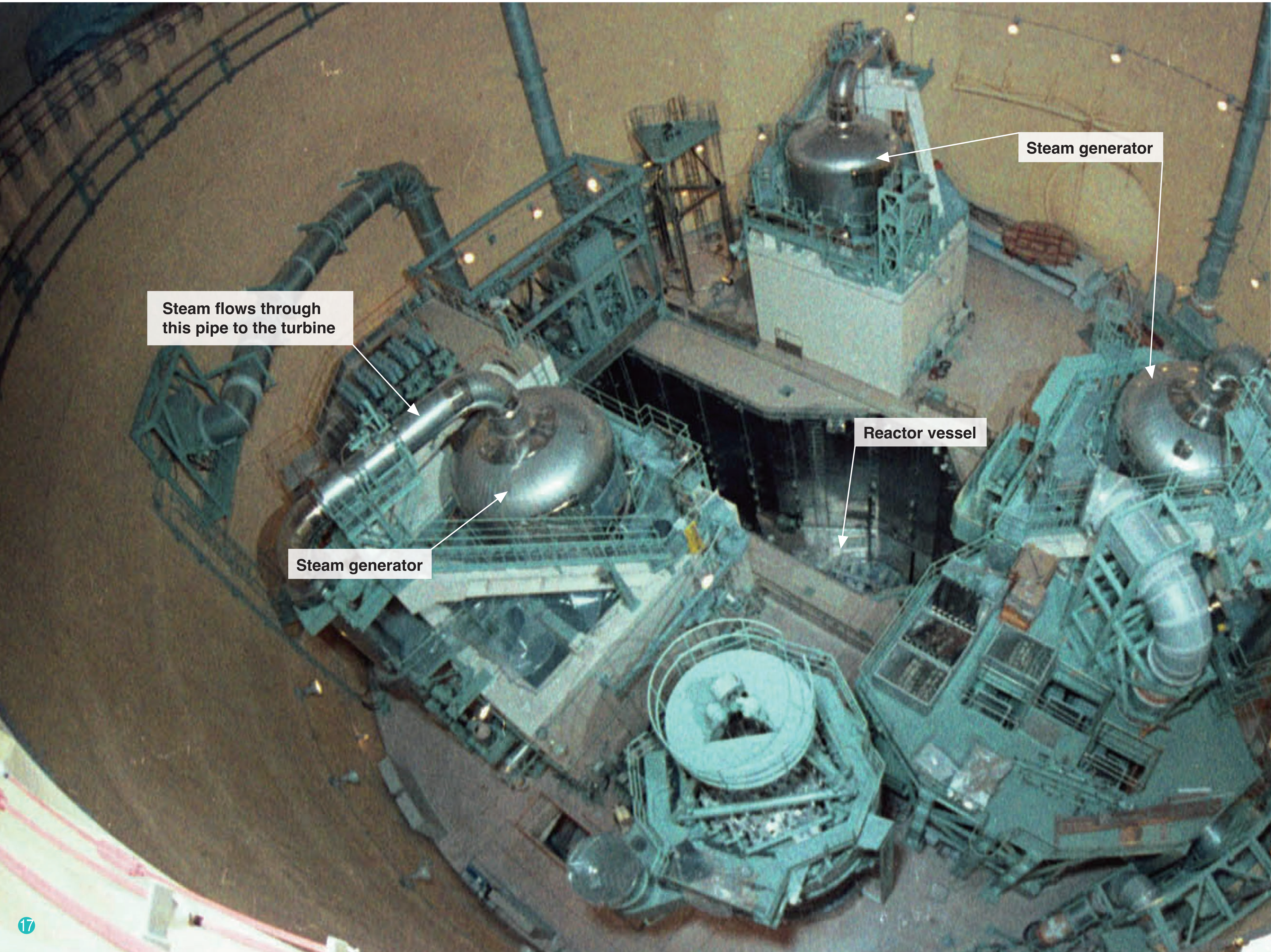
Taking specimens for environmental tests (soil)

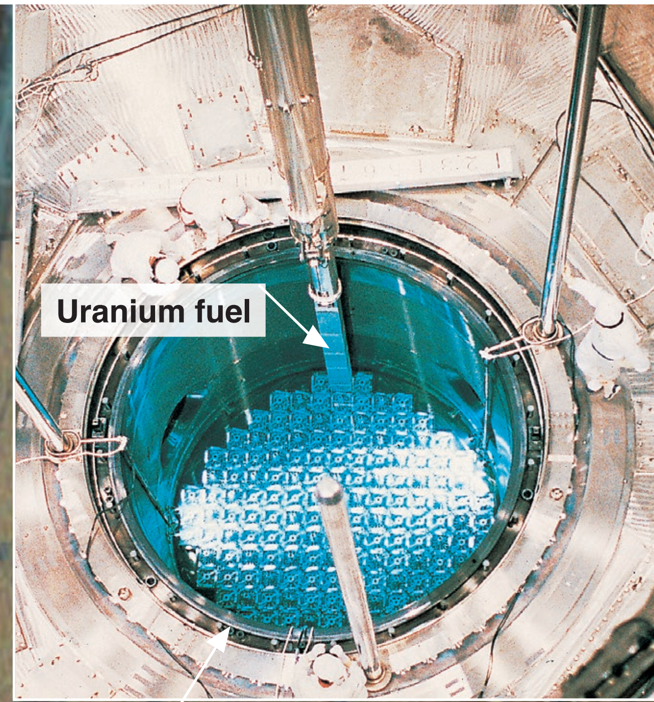
Nuclear Fuel Recycling

After mined uranium has been processed and used for electricity generation, it passes through a series of processes until it is used again as fuel. This is called nuclear fuel recycling.



Inside the Containment Vessel



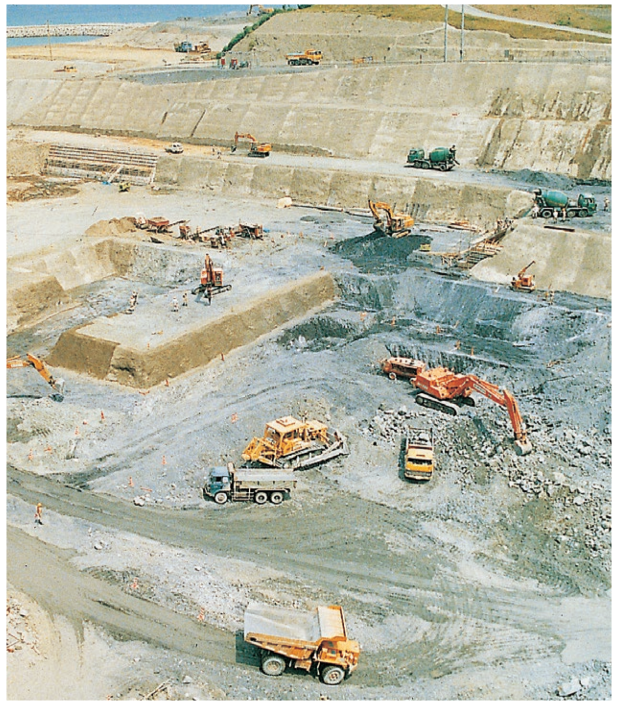


A Photo History of the Construction

● Major Events

Item	Unit 1	Unit 2
Construction plan announced	April 21, 1970	March 29, 1977
Power Resources Development Adjustment Council	March 12, 1976 (68 meetings)	July 14, 1978 (75 meetings)
Construction permit granted	December 17, 1977	December 22, 1980
Construction start (Foundation excavation commenced)	January 24, 1979	May 7, 1981
Major equipment installation completed	April 8, 1983	November 14, 1984
Commercial operation	July 4, 1984	November 28, 1985

▼ Foundation excavation work



The foundations for containment vessel were laid directly on the firm bedrock stratum, at a depth of approx. 30 meters below ground level.

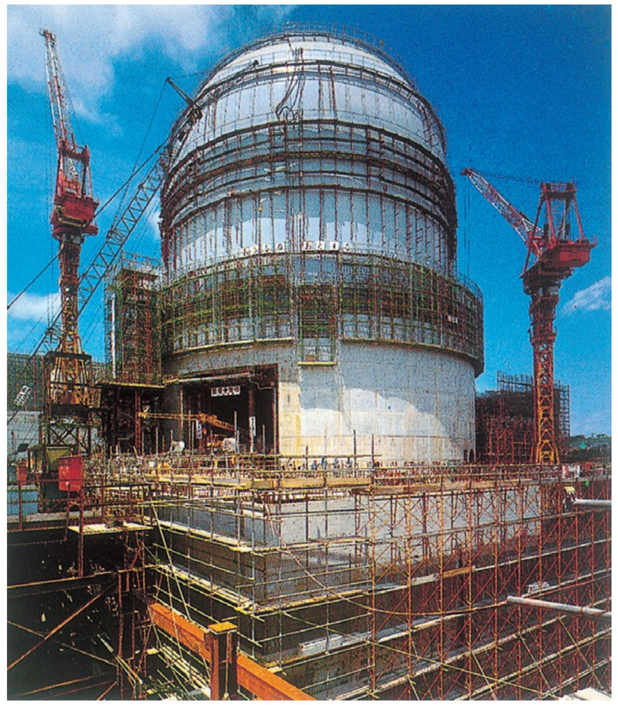
About 900,000 cubic meters of earth and rock was removed for this excavation operation.

Excavations for Unit 2 went much faster than the earlier excavations for Unit 1, due to refinements in the excavation method, and in the use of larger earth-moving machinery.

▼ Construction of the main buildings

The main buildings consist of five structures, including the Reactor Building, the Reactor Auxiliary Building, an intermediate building, the Control Building, and the Turbine Building, and stretch from the bedrock foundations approx. 30 meters below ground to the highest point at approx. 60 meters above ground, for a complex that is nearly 100 meters high.

▼ Installation of containment vessel



Approx. 170 steel plates, each 38 millimeters thick, 7 meters wide, and 10 meters long, was linked together to assemble the containment vessel.

Inspections were conducted at every stage of the construction process, with the final inspection consisting of raising the air pressure inside the containment vessel to 0.27 MPa (2.8 kg/cm^2) as a check for possible leaks.

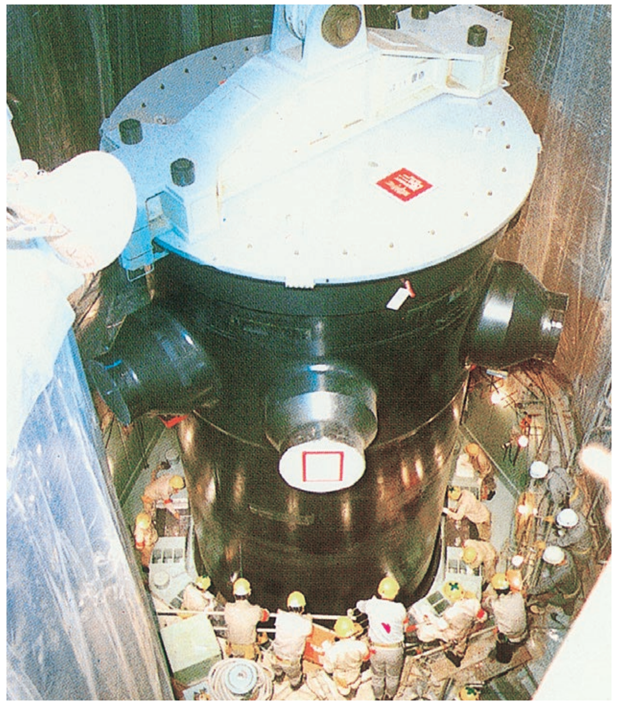
▼ Installation of the turbine and generator

The turbine was assembled from one high-pressure turbine and three low-pressure turbines, arranged skewer-like in a line. The rotor weighs approx. 350 tons and extends approx. 40 meters.

The generator consists of a stator, weighing approx. 420 tons, and a 177 ton rotator, for a total weight of approx. 600 tons.

The turbine, generator, and exciter are arranged in a straight line extending approx. 60 meters, and rotate as one unit.

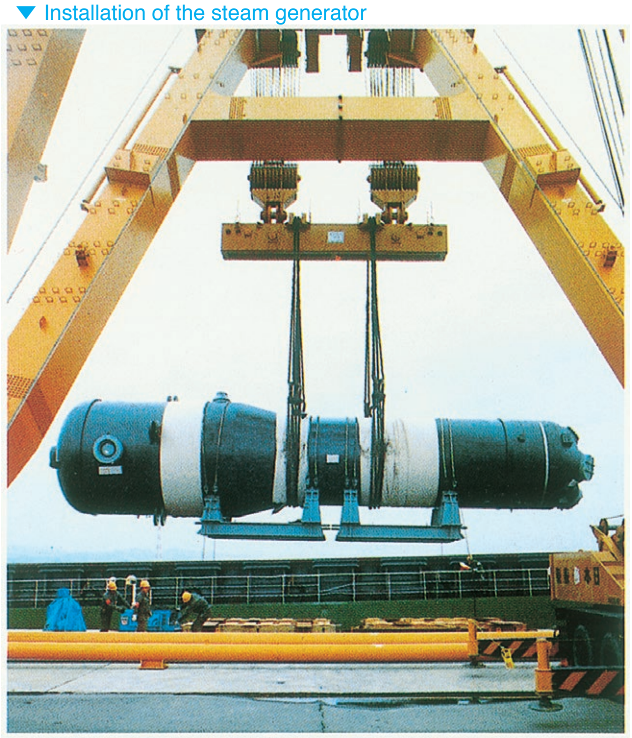
▼ Installation of the reactor



The reactor vessel is a cylindrical low alloy steel container weighing approx. 320 tons, and with a diameter of approx. 4 meters, length of approx. 12 meters, and thickness of approx. 20 centimeters.

The reactor vessel was brought ashore from an unloading wharf built specially for the power station, and then transported on rollers to the containment vessel site and lowered into the center of the lowest excavated point for installation.

▼ Installation of the steam generator



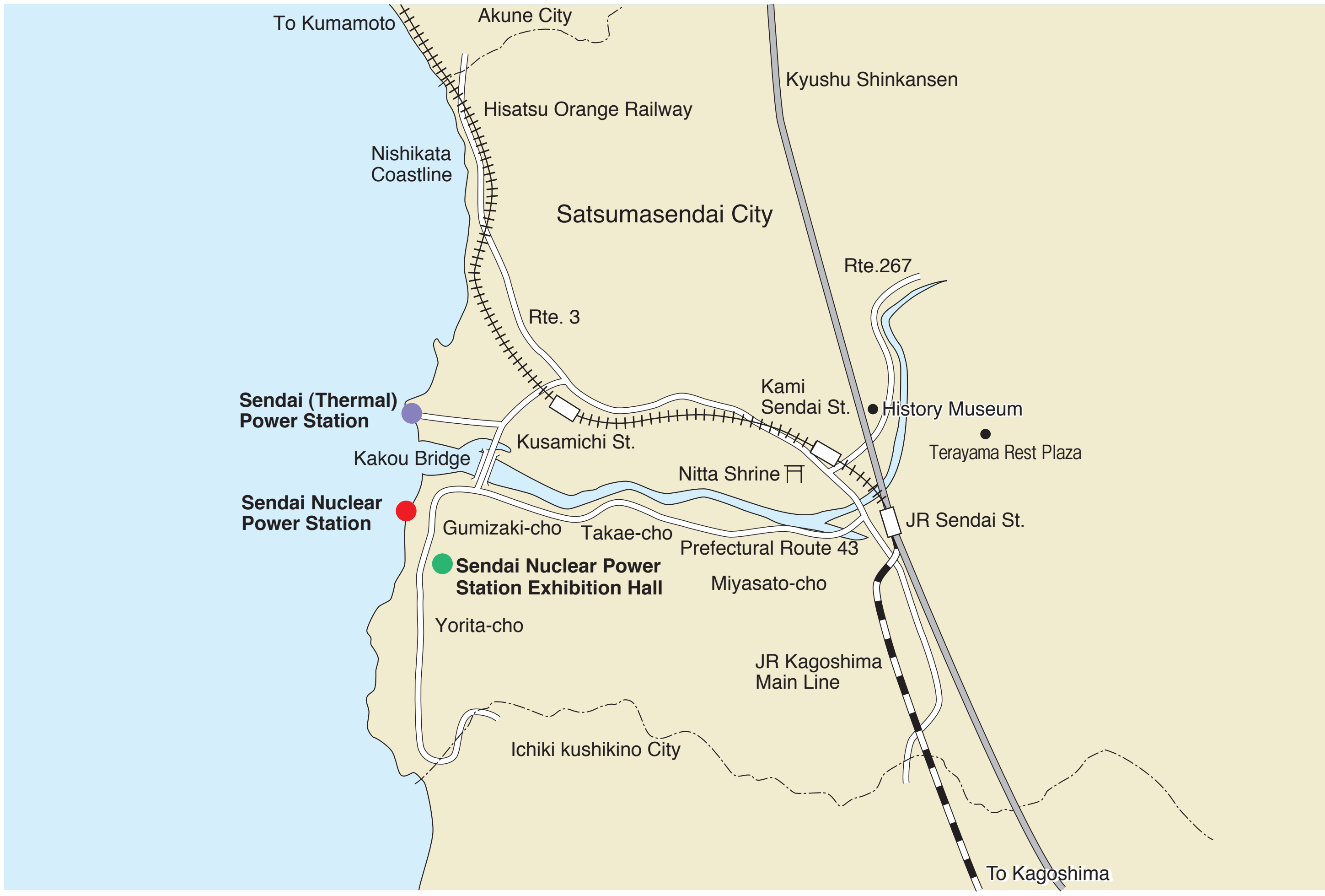
The steam generator is a cylindrical vessel weighing 315 tons with a length of 20.6 meters. As with the reactor vessel, it was unloaded at the specially built wharf, transported on rollers to the site, and installed near the reactor inside the containment vessel.

▼ Central control room monitoring daily operation

The core point for all operations in the power station is the control room.

The control room houses approx. 1,800 switches, approx. 1,800 alarms, and approx. 1,200 instruments for Units 1 and 2, and operators are always on station monitoring conditions.

The Sendai Nuclear Power Station Exhibition Hall



Life-size mock-up of a reactor in the Exhibition Hall

Guide to the Exhibition Hall

● Access

■ Bus: Take the community bus Takae/Tsuchikawa Line from Sendai Station, and get off at the Tenjikanmae stop (Exhibition Hall stop). Takes about 30 minutes.

■ Taxi: About 25 minutes from Sendai Station.

● Hours: 9 a.m. to 5 p.m. admission free

● Closed: New Year's holidays (December 29 to January 1)

● Group tours are requested to apply in advance.
Exhibition Hall Reception: Tel (0996) 27-3506

Sites of Interest Near the Power Station

Nitta Shrine
● Miyauchi-cho, Satsumasendai City

Terayama Rest Plaza
● Amadatsu-cho, Satsumasendai City

History Museum
● Chugo-cho, Satsumasendai City

Nishikata Coastline (Doll Rock)
● Nishikata-cho, Satsumasendai City

KYUSHU ELECTRIC
POWER CO.,INC.

For more information on the Sendai Nuclear Power Station,
visit our web site at: http://www.kyuden.co.jp/sendai_index.html